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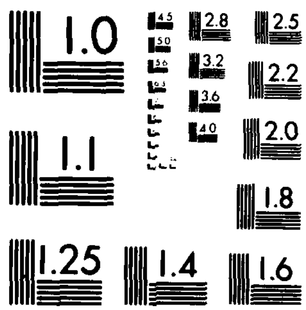

MICROCOPY RESOLUTION TEST CHART
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A Proposed Standard Climate for Evaluating Rocket Exhaust Secondary Smoke Formation and Visibility, Revision 1

by

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(11) Jan 79

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NAVAL WEAPONS CENTER
China Lake, California 93555

FOREWORD

This report presents the results of work which was supported by the Naval Air Systems Command, "Advanced Reliable Solid Propulsion Design," Propulsion Administrators, Mr. Robert Heitkotter (NAVAIR) and Dr. Charles Thelen (NWC) and by the Naval Sea Systems Command, "Plume Low Signature Requirements for Point/Area Defense Solid Propellant Motors," J. Murrin and R. Cassel. The Program Manager was Mr. George Buckle, Naval Ordnance Station, Indian Head, MD.

This report is a revision of NWC TM 3638. Since the original report was published in November 1978, an error in the computer program that was used to generate much of the data in the report has been corrected. As a result, Tables 2 throught 15 and the computer program in the Appendix have been changed. Also, a slight change has been made in the percent value in Figure 4.

This report is issued for use at the working level only and does not reflect an official position of the Naval Weapons Center.

Duane H. Williams
Head, Advanced Technology Division
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Under certain climatic conditions rocket motor exhaust plumes can form contrails which are highly visible at long ranges. It is difficult to predict accurately the formation and visibility of these contrails unless the important climatic factors (temperature and moisture content) are known. This report proposes a preliminary definition of a climate at 40°N and 50°N latitude for altitudes from 2-15 km based on a review of relevant literature. Both temperature and moisture content are expressed in terms of mean values and standard deviations so that the probability of occurrence of any climatic conditions can be estimated.

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ABSTRACT

Under certain climatic conditions rocket motor exhaust plumes can form contrails which are highly visible at long ranges. It is difficult to predict accurately the formation and visibility of these contrails unless the important climatic factors (temperature and moisture content) are known. This report proposes a preliminary definition of a climate at 40°N and 50°N latitude for altitudes from 2-15 km based on a review of relevant literature. Both temperature and moisture content are expressed in terms of mean values and standard deviations so that the probability of occurrence of any climatic conditions can be estimated.

INTRODUCTION

Moisture laden exhaust contrails can greatly increase the detectability of missiles and aircraft. The problem is most severe for those rocket motors which contain, as products of combustion, water soluble gas and particle species which increase the propensity for moisture condensation. Therefore, avoidance of contrail formation is an important design criterion for certain missions required of modern missile propulsion systems. Changes made in missile propellant ingredients in order to meet this criterion often result in reduced rocket motor total energy. To minimize this compromise of motor energy it is important, in the system design phase, to perform trade-off analyses of the effects of energy and contrail formation on the performance of a missile's mission.

Previous studies have yielded techniques for predicting missile performance[1] and the visibility of primary smoke* trails. Although techniques have also been developed for predicting the formation and visibility of secondary smoke** contrails[3,4], these predictions require inclusion of ambient temperature and humidity values.

Temperature and humidity values needed for incorporation in contrail predictions may be obtained in several ways:

1. Use specific values based on specific measurements
2. Use standard climatic values[5,6]

* "Primary smoke" is composed of the solid effluent from propulsion systems.

** "Secondary smoke" is formed by condensation of plume and atmospheric water on the microscopic particle efflux; it often contains water soluble species too.

1 Naval Weapons Center. *Tactical Missile Encounter (TAME) Simulation Computer Program*, by D. R. Peters, R. D. Feldman, H. Sobel and M. J. Stevens. China Lake, Calif., NWC, March 1970. (NWC TP 4866, publication UNCLASSIFIED.)

2 A. C. Victor and S. H. Brell. "A Simple Method for Predicting Rocket Exhaust Smoke Visibility," *J SPACECRAFT AND ROCKETS*, Vol. 14, No. 9 (September 1977), pp. 526-533.

3 Naval Weapons Center. "Computer Codes for Predicting Secondary Smoke Formation in Free Jets and Smoke Chambers," by A. C. Victor. China Lake, Calif., NWC, February 1978. (NWC TM 3361, publication UNCLASSIFIED.)

4 H. Hoshizaki, et. al. "Plume Visibility Detection Study," presented at the *10th JANNAF Plume Technology Meeting, 14-17 September 1977*. (NWC TM 3361, publication UNCLASSIFIED.)

5 *U.S. Standard Atmosphere 1962*. U.S. Government Printing Office, December 1972, Washington, D.C.

6 Air Force Cambridge Research Laboratories, *Handbook of Geophysics and Space Environments*, S. L. Valley, Ed. Bedford Mass., 1965, Chapter 3. (UNCLASSIFIED.)

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3. Use tabulated climatic values (footnotes 5 and 6) and make the contrail predictions for a world-wide, year round, range of climates
4. Use a statistically defined climate model (humidity, temperature, altitude) which corresponds to observations and makes the contrail prediction at statistically significant points in the climate

Each of these methods of selecting climatic values has distinct advantages and disadvantages. The first method is useful only to verify the predictive technique by comparison with previously made measurements; it has no relevance for system design studies.

The second method is useful for a quick look approach, but it cannot provide probabilities of contrail formation which are needed in the design study.

The third method is capable of generating the predictions needed in design studies, but at an excessive cost, because of the many climate conditions involved. This method is most useful for evaluating contrail formation in specific operation theaters.

The fourth method is essentially a condensation of the third method in that weather statistics are included in the climate model. Thus with only a few calculations the probability of contrail formation for a specific missile propulsion system can be predicted as a function of altitude and latitude.

This report presents a simple model climate based on the fourth method above, which averages annual climate variations at specific latitudes. Latitudes of 40°N and 50°N were chosen as being typical of the United States and Western Europe, respectively.

A more complex statistical model, based on accumulated world-wide statistics, although desirable, was beyond the manpower and funding limits of the projects which supported this study. Such a model would be capable of predicting weather probabilities on any specific date, whereas the model described in this report can only predict probabilities for an arbitrary date.

CLIMATE MODEL

The climate model needed for contrail prediction has four elements:

1. Mean temperature as a function of altitude
2. Standard deviation of temperature as a function of altitude
3. Mean humidity as a function of altitude
4. Standard deviation of humidity as a function of altitude

TEMPERATURE MODEL

Temperature as a function of altitude has been measured carefully for many years, and sufficient data are reported to define both elements 1 and 2 above. From Table 3-9 in *Handbook of Geophysics and Space Environments* (footnote 6), Equations 1 and 2 have been generated to represent mean annual temperature, in degrees Celsius, at 40°N and 50°N latitude respectively, as functions of altitude (y) in km up to 20 km.

$$T_{40°N} = 28.56 - 10.618y + 0.3168y^2 \quad (1)$$

$$T_{50°N} = 12.95 - 8.774y + 0.2738y^2 \quad (2)$$

Equations 3 and 4 represent the January and July mean variations of temperature about the annual mean:

$$t_{40°N} = 8.0 - 0.56y + 0.0153y^2 \quad (3)$$

$$t_{50°N} = 10.3 - 0.7y + 0.0167y^2 \quad (4)$$

The mean temperature in January and July are given by:

$$T(\text{jan})_{40°N} = T_{40°N} - t_{40°N} \qquad \text{0 to 12 km altitude}$$
$$= T_{40°N} + t_{40°N} \qquad \text{14 to 20 km}$$
$$= T_{40°N} \qquad \text{12 to 14 km}$$

$$T(\text{july})_{40°N} = T_{40°N} + t_{40°N} \qquad \text{0 to 12 km}$$
$$= T_{40°N} - t_{40°N} \qquad \text{14 to 20 km}$$
$$= T_{40°N} \qquad \text{12 to 14 km}$$

$$T(\text{jan})_{50°N} = T_{50°N} - t_{50°N}$$
$$T(\text{july})_{50°N} = T_{50°N} + t_{50°N} \qquad \text{0 to 20 km}$$

The standard deviations (σ) about the January and July mean values (up to 15 km) are approxmiately:

$$\sigma(\text{jan})_{40°N} = \pm 5°C$$
$$\sigma(\text{july})_{40°N} = \pm 3°C$$

$$\sigma(\text{jan})_{50°N} = \pm 6°C$$
$$\sigma(\text{july})_{50°N} = \pm 4°C$$

Therefore upper and lower likely (1σ) extremes of temperature are given approximately by

$$T_+ = T + t + \sigma(\text{july}) \tag{5}$$

$$T_- = T - t - \sigma(\text{jan}) \tag{6}$$

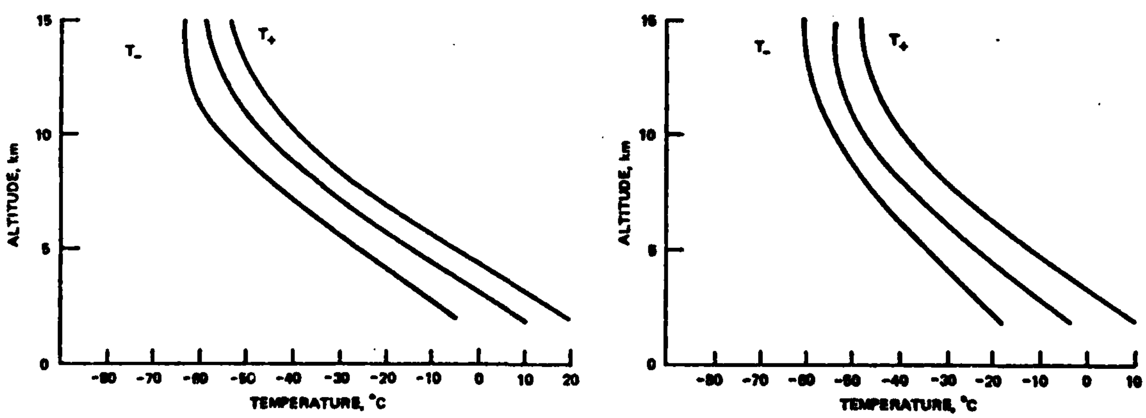
except at 40°N latitude above 14 km where the upper extreme is given by:

$$T_+ = T + t + \sigma(\text{jan}) \tag{7}$$

and lower by:

$$T_- = T - t - \sigma(\text{july}) \tag{8}$$

The temperature models are shown graphically in Figure 1. The mathematical models defined by Equations 1 through 8 are not intended for use outside the altitude range 2-15 km.



a. 40°N Latitude. b. 50°N Latitude.

FIGURE 1. Temperature Models.

HUMIDITY MODEL

The information in footnote 6 and more recent measurements[7] show that mean atmospheric moisture content can be well represented by Equation 9 for the mixing ratio W = mass of atmospheric water/mass air, in parts per million,

$$W = 10^{(3.7 - 0.192y)} \qquad \text{for 0-10 km altitude}$$

$$= 10^{4.13 - 0.235y)} \qquad \text{for 10-15 km altitude} \tag{9}$$

up to an altitude of 15 km (about 50,000 feet). The data in footnote 7 indicate that the fractional standard deviation about the means is about 0.6 at all altitudes.

The actual water vapor pressure (e_v) is obtained from the mixing ratio by Equation 10

$$e_v = \frac{PW \times 10^{-6}}{0.622 + W \times 10^{-6}} \cong \frac{PW}{0.622 \times 10^6} \tag{10}$$

in the units of atmospheric pressure (P).

Standard atmospheric pressure (footnote 6) as a function of altitude is given in Table 1.

TABLE 1. Atmospheric Pressure (P)[a] as a Function of Altitude (y).

y, km	P, mb	y, km	P, mb
0	1013	12	193
2	795	14	141
4	616	16	103
6	472	18	75.0
8	356	20	54.7
10	264	22	40.0

[a] The following constants may be used to convert to other pressure units:

mb x 0.00098692 = atmospheres

mb x 10^8 = pascals (N m^{-2})

mb x 0.014504 = pounds/inch^2

mb x 0.7502 = mm of mercury at 0°C

[7] Air Force Cambridge Research Laboratories, "Humidity Up to the Mesopause," by N. Sissenwine, D. D. Granthan and H. A. Samela. Bedford, Mass., October 1968. (AFCRL-68-0530, AD 679996, UNCLASSIFIED.)

By combining Equations 9 and 10, Table 1, and water vapor pressure curves (footnote 3, *Handbook of Chemistry and Physics*[8] or Figure 2), one can describe the humidity in terms of a frost (or dew) point. This is shown in Figure 3.

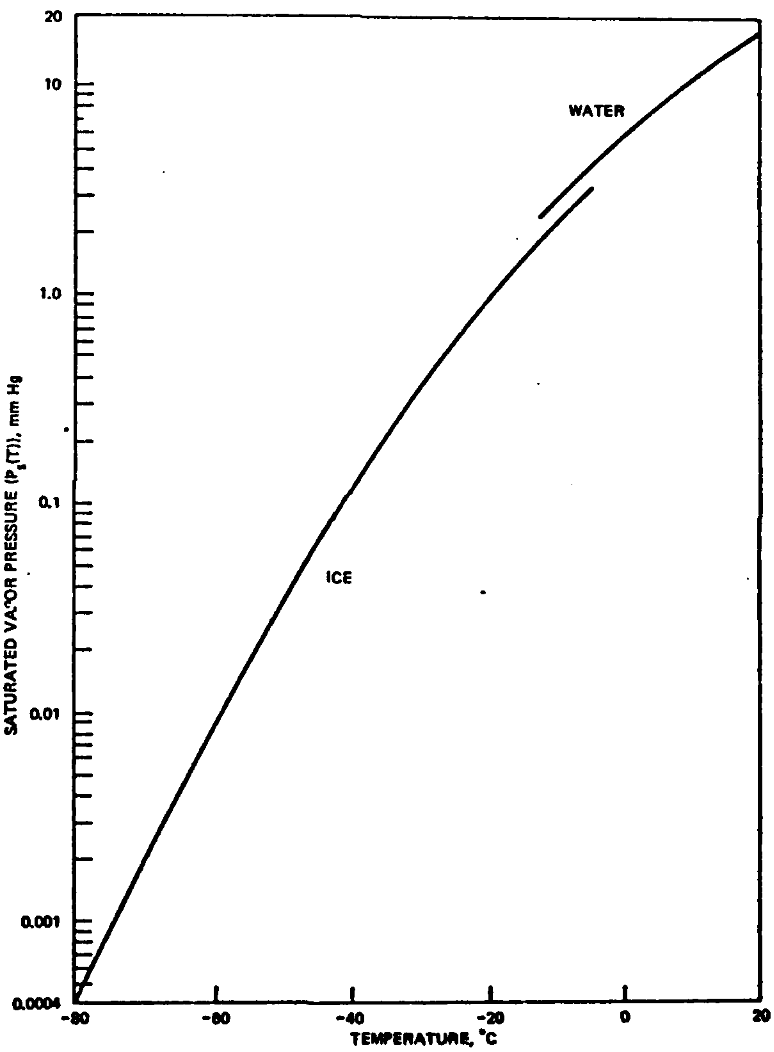


FIGURE 2. Temperature Dependence of the Equilibrium or Saturated Vapor Pressure of Pure Water.

[8] The Chemical Rubber Co. *Handbook of Chemistry and Physics.* R. C. Weast and S. M. Selby, Ed., 47th ed. (1966), pp. D-105, 106.

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It is interesting to note that if one overlays a transparency of Figure 3 on Figures 1a and 1b, some information on the probability of cloud formation emerges. If the frost point is greater than the ambient temperature, clouds will form.

The relative humidity at a temperature is the ratio of the water vapor pressure to the saturation pressure of water at that temperature ($p_s(T)$). If the calculated relative humidity is greater than unity, clouds will form. In the presence of clouds, contrail formation does little to increase the visibility (detection probability) of a missile. Therefore we are only interested in those portions of Figures 1 and 3 for which the frost point is lower than the ambient temperature.

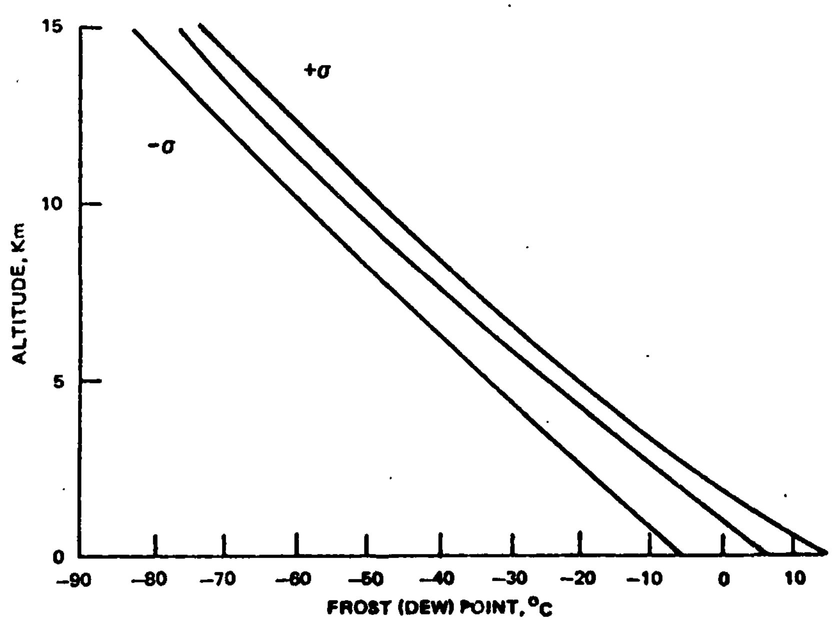

FIGURE 3. Frost (Dew) Point Temperature vs. Altitude from Humidity Model. (Fractional standard deviation is ±0.6 of W or e_v.)

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COMPOUND MODEL

In order to move ahead from this stage of the model, two assumptions are necessary: (1) the relationship between the temperature and humidity models and (2) the shapes of the temperature and humidity probability distributions.

Independence of the temperature and humidity is assumed, and the shapes of the probability curves are assumed to be "triangular" as shown in Figure 4. These assumptions were made in lieu of readily accessible contradictory data.

Following this assumption, it is possible to calculate cumulative probabilities of any value of temperature and humidity and of the joint probability of any temperature-humidity pair. The probability of real interest is the joint probability that temperature will be below a specified value *and* that humidity will be above a certain value. The joint probabilities and relative humidities for this set are shown in Tables 2 through 15 for the altitude range of 2-14 km at both 40°N and 50°N lattitude. These tables were generated by the computer program given in the Appendix.

The number pairs enclosed by the rectangles in Tables 2 through 15 represent an 11 by 11 matrix of joint probabilities and relative humidities. The upper number in each pair is the joint probability; the lower, the relative humidity. The joint probability represents the probability that temperature is lower than the value in the far left column (outside the rectangle) *and* that humidity is greater than the value in the top row (outside the rectangle). The right-most column in each table is the probability that the temperature is less than the value in the left-most column. The lowest row in each table is the probability that the humidity (e_v in mm Hg) is greater than the value in the top-most row. The second column in each table is the saturated vapor pressure, $p_s(T)$ or PSAT, associated with the temperature, TC, in the first

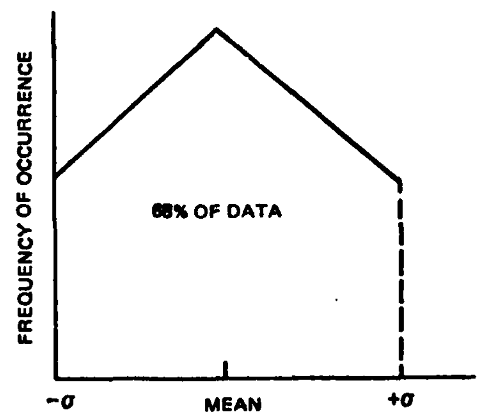

FIGURE 4. Assumed Probability Curve Shape for Temperature and Humidity.

column. The relative humidity is just the ratio $e_v/p_s(T)$. Regions in Tables 2 through 15 where the relative humidity is greater than unity correspond to natural cloud formation.

For example, if one looks at the central pair (the 6,6 matrix position) in the matrix of Table 2, the joint probability is 0.25; the relative humidity is 0.256 (or 25.6%). This pair corresponds to a temperature of 7.6°C (which has a saturated vapor pressure of 7.76 mm Hg) and an actual vapor pressure of e_v = 1.98 mm Hg. There is a 0.5 probability that temperature is less than 7.6°C at this altitude and latitude and also a 0.5 probability that the humidity is greater than 1.98 mm Hg.

CONCLUSIONS

A simple model for defining the atmospheric temperature and humidity at regions of operational interest for tactical missiles in the temperate zone of the earth's northern hemisphere has been described in this report. With this model one can define a probability distribution for temperature and humidity on any *arbitrary day.*

Definition of probabilities of these atmospheric variables may also be desirable for any *particular day.* In order to obtain appropriate values for this approach it will be necessary to computerize extensive records of atmospheric fluctuations and derive appropriate statistical and perhaps analytical approaches which are beyond the funding limits of the projects which supported this study.

TABLE 2. Climate for 40°N Latitude
2.0 km Altitude 795.0 MB Pressure
(Joint Probability/Relative Humidity).

****

EV, MM HG

TC DEG C	PSAT MM HG	.794+00	.103+01	.127+01	.151+01	.175+01	.198+01	.222+01	.246+01	.270+01	.294+01	.318+01	PROB TEMP IS LT TC
18.5		.744+00	.696+00	.640+00	.578+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.159+02	.500-01	.650-01	.600-01	.950-01	.110+00	.125+00	.140+00	.155+00	.170+00	.185+00	.200+00	
16.3		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.138+02	.574-01	.746-01	.918-01	.109+00	.126+00	.143+00	.161+00	.178+00	.195+00	.212+00	.230+00	
14.2		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.120+02	.661-01	.859-01	.106+00	.126+00	.145+00	.165+00	.185+00	.205+00	.225+00	.244+00	.264+00	
12.0		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.104+02	.762-01	.991-01	.122+00	.145+00	.168+00	.191+00	.213+00	.236+00	.259+00	.282+00	.305+00	
9.8		.508+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.900+01	.882-01	.115+00	.141+00	.168+00	.194+00	.221+00	.247+00	.273+00	.300+00	.326+00	.353+00	
7.6		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.688-01	.500
	.776+01	.102+00	.133+00	.164+00	.194+00	.225+00	.256+00	.287+00	.317+00	.348+00	.379+00	.409+00	
5.4		.354+00	.331+00	.305+00	.275+00	.242+00	.206+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.667+01	.119+00	.155+00	.191+00	.226+00	.262+00	.298+00	.333+00	.369+00	.405+00	.441+00	.476+00	
3.2		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.571+01	.139+00	.181+00	.222+00	.264+00	.306+00	.347+00	.389+00	.431+00	.473+00	.514+00	.556+00	
1.0		.222+00	.208+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.488+01	.163+00	.211+00	.260+00	.309+00	.358+00	.407+00	.455+00	.504+00	.553+00	.602+00	.650+00	
-1.2		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.416+01	.191+00	.248+00	.305+00	.363+00	.420+00	.477+00	.534+00	.591+00	.649+00	.706+00	.763+00	
-3.3		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.354+01	.224+00	.292+00	.359+00	.427+00	.494+00	.561+00	.629+00	.696+00	.763+00	.831+00	.898+00	
		.862	.807	.742	.670	.589	.500	.411	.330	.258	.194	.138	

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TABLE 3. Climate for 40°N Latitude
4.0 km Altitude 616.0 MB Pressure
(Joint Probability/Relative Humidity).

EV, MM HG

TC DEG C	PSAT MM HG	.254+00	.330+00	.407+00	.483+00	.559+00	.635+00	.712+00	.788+00	.864+00	.940+00	.102+01	PROB TEMP IS LT TC
.2		.744+00	.696+00	.640+00	.578+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.459+01	.554-01	.720-01	.887-01	.105+00	.122+00	.139+00	.155+00	.172+00	.188+00	.205+00	.222+00	
-1.8		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.396+01	.642-01	.835-01	.103+00	.122+00	.141+00	.161+00	.180+00	.199+00	.218+00	.238+00	.257+00	
-3.8		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.341+01	.745-01	.969-01	.119+00	.142+00	.164+00	.186+00	.209+00	.231+00	.253+00	.276+00	.298+00	
-5.8		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.293+01	.867-01	.113+00	.139+00	.165+00	.191+00	.217+00	.243+00	.269+00	.295+00	.321+00	.347+00	
-7.8		.508+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.251+01	.101+00	.131+00	.162+00	.192+00	.223+00	.253+00	.283+00	.314+00	.344+00	.374+00	.405+00	
-9.8		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.688-01	.500
	.215+01	.118+00	.154+00	.189+00	.225+00	.260+00	.295+00	.331+00	.366+00	.402+00	.437+00	.473+00	
-11.8		.354+00	.331+00	.305+00	.275+00	.242+00	.206+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.184+01	.138+00	.180+00	.221+00	.263+00	.304+00	.346+00	.387+00	.429+00	.471+00	.512+00	.554+00	
-13.8		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.157+01	.162+00	.211+00	.260+00	.308+00	.357+00	.406+00	.455+00	.503+00	.552+00	.601+00	.649+00	
-15.8		.222+00	.208+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.109+01	.232+00	.302+00	.372+00	.442+00	.511+00	.581+00	.651+00	.721+00	.790+00	.860+00	.930+00	
-17.8		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.907+00	.280+00	.364+00	.448+00	.532+00	.616+00	.700+00	.784+00	.868+00	.952+00	.104+01	.112+01	
-19.8		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.750+00	.339+00	.440+00	.542+00	.643+00	.745+00	.845+00	.948+00	.105+01	.115+01	.125+01	.135+01	
		.862	.807	.742	.670	.589	.500	.411	.330	.258	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

TABLE 4. Climate for 40°N Latitude 6.0 km Altitude 472.0 MB Pressure (Joint Probability/Relative Humidity).

EV, MM HG

TC DEG C	PSAT MM HG	.604-01	.105+00	.129+00	.153+00	.177+00	.201+00	.225+00	.249+00	.273+00	.298+00	.322+00	PROB TEMP IS LT TC
-15.6		.744+00	.696+00	.640+00	.578+00	.506+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.112+01	.716-01	.931-01	.115+00	.136+00	.158+00	.179+00	.200+00	.222+00	.243+00	.265+00	.286+00	
-17.4		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.947+00	.849-01	.110+00	.136+00	.161+00	.187+00	.212+00	.238+00	.263+00	.289+00	.314+00	.340+00	
-19.2		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.796+00	.101+00	.131+00	.162+00	.192+00	.222+00	.253+00	.283+00	.313+00	.343+00	.374+00	.404+00	
-21.1		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.668+00	.120+00	.157+00	.193+00	.229+00	.265+00	.301+00	.337+00	.373+00	.410+00	.446+00	.482+00	
-22.9		.506+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.558+00	.144+00	.187+00	.230+00	.274+00	.317+00	.360+00	.403+00	.446+00	.490+00	.533+00	.576+00	
-24.7		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.688-01	.500
	.466+00	.173+00	.224+00	.276+00	.328+00	.380+00	.432+00	.483+00	.535+00	.587+00	.639+00	.691+00	
-26.6		.354+00	.331+00	.305+00	.275+00	.242+00	.205+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.388+00	.208+00	.270+00	.332+00	.394+00	.457+00	.519+00	.581+00	.643+00	.706+00	.768+00	.830+00	
-28.4		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.321+00	.250+00	.325+00	.400+00	.475+00	.550+00	.625+00	.701+00	.776+00	.851+00	.926+00	.100+01	
-30.3		.222+00	.208+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.266+00	.302+00	.393+00	.484+00	.575+00	.665+00	.755+00	.847+00	.938+00	.103+01	.112+01	.121+01	
-32.1		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.219+00	.367+00	.477+00	.587+00	.697+00	.807+00	.917+00	.103+01	.114+01	.125+01	.136+01	.147+01	
-33.9		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.180+00	.446+00	.580+00	.714+00	.847+00	.981+00	.112+01	.125+01	.136+01	.152+01	.165+01	.178+01	
		.862	.807	.742	.670	.589	.500	.411	.330	.258	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

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TABLE 5. Climate for 40°N Latitude
8.0 km Altitude 356.0 MB Pressure
(Joint Probability/Relative Humidity).

EV, MM HG

TC DEG C	PSAT MM HG	.251-01	.326-01	.401-01	.476-01	.551-01	.625-01	.702-01	.777-01	.852-01	.927-01	.100+00	PROB TEMP IS LT TC
-28.6		.744+00	.696+00	.640+00	.578+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.315+00	.795-01	.103+00	.127+00	.151+00	.175+00	.199+00	.223+00	.246+00	.270+00	.294+00	.318+00	
-30.3		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.264+00	.947-01	.123+00	.152+00	.180+00	.208+00	.237+00	.265+00	.294+00	.322+00	.351+00	.379+00	
-32.0		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.221+00	.113+00	.147+00	.181+00	.215+00	.249+00	.283+00	.317+00	.351+00	.385+00	.419+00	.453+00	
-33.7		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.185+00	.136+00	.176+00	.217+00	.258+00	.298+00	.339+00	.380+00	.421+00	.461+00	.502+00	.543+00	
-35.4		.508+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.154+00	.163+00	.212+00	.261+00	.310+00	.358+00	.407+00	.456+00	.505+00	.554+00	.603+00	.652+00	
-37.1		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.688-01	.500
	.126+00	.196+00	.255+00	.314+00	.373+00	.432+00	.491+00	.550+00	.608+00	.667+00	.726+00	.785+00	
-38.8		.354+00	.331+00	.305+00	.275+00	.242+00	.205+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.106+00	.237+00	.308+00	.379+00	.450+00	.522+00	.593+00	.664+00	.735+00	.806+00	.877+00	.948+00	
-40.5		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.873-01	.287+00	.373+00	.459+00	.546+00	.632+00	.718+00	.804+00	.890+00	.976+00	.106+01	.115+01	
-42.2		.222+00	.206+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.718-01	.349+00	.453+00	.556+00	.663+00	.767+00	.872+00	.977+00	.108+01	.119+01	.129+01	.140+01	
-43.9		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.590-01	.425+00	.552+00	.680+00	.807+00	.935+00	.106+01	.119+01	.132+01	.144+01	.157+01	.170+01	
-45.6		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.483-01	.519+00	.675+00	.831+00	.986+00	.114+01	.130+01	.145+01	.161+01	.177+01	.192+01	.208+01	
		.862	.807	.742	.670	.589	.500	.411	.330	.258	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

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TABLE 6. Climate for 40°N Latitude 10.0 km Altitude 264.0 MB Pressure (Joint Probability/Relative Humidity).

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EV, MM HG

TC DEG C	PSAT MM HG	.767-02	.998-02	.123-01	.146-01	.169-01	.192-01	.215-01	.238-01	.261-01	.284-01	.307-01	PROB TEMP IS LT TC
-39.0		.744+00	.696+00	.640+00	.578+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.103+00	.743-01	.965-01	.119+00	.141+00	.163+00	.186+00	.208+00	.230+00	.253+00	.275+00	.297+00	
-40.6		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.864-01	.888-01	.115+00	.142+00	.169+00	.195+00	.222+00	.249+00	.275+00	.302+00	.329+00	.355+00	
-42.2		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.721-01	.107+00	.138+00	.170+00	.202+00	.234+00	.265+00	.298+00	.330+00	.362+00	.394+00	.426+00	
-43.8		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.599-01	.126+00	.166+00	.205+00	.243+00	.282+00	.320+00	.358+00	.397+00	.435+00	.474+00	.512+00	
-45.4		.508+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.497-01	.154+00	.201+00	.247+00	.293+00	.339+00	.386+00	.432+00	.478+00	.525+00	.571+00	.617+00	
-46.9		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.688-01	.500
	.412-01	.186+00	.242+00	.298+00	.354+00	.410+00	.466+00	.522+00	.578+00	.634+00	.690+00	.746+00	
-48.5		.354+00	.331+00	.305+00	.275+00	.242+00	.206+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.340-01	.226+00	.294+00	.362+00	.429+00	.497+00	.565+00	.633+00	.700+00	.768+00	.836+00	.904+00	
-50.1		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.280-01	.275+00	.357+00	.439+00	.522+00	.604+00	.686+00	.769+00	.851+00	.934+00	.102+01	.110+01	
-51.7		.222+00	.208+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.229-01	.335+00	.435+00	.535+00	.636+00	.736+00	.835+00	.937+00	.104+01	.114+01	.124+01	.134+01	
-53.3		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.188-01	.409+00	.532+00	.654+00	.777+00	.900+00	.102+01	.115+01	.127+01	.139+01	.151+01	.164+01	
-54.9		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.153-01	.501+00	.652+00	.802+00	.952+00	.110+01	.125+01	.140+01	.155+01	.170+01	.185+01	.201+01	
		.862	.607	.742	.670	.589	.500	.411	.330	.258	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

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TABLE 7. Climate for 40°N Latitude
12.0 km Altitude 193.0 MB Pressure
(Joint Probability/Relative Humidity).

EV, MM HG

TC DEG C	PSAT MM HG	.190-02	.247-02	.304-02	.361-02	.418-02	.475-02	.532-02	.589-02	.646-02	.703-02	.760-02	PROB TEMP IS LT TC
-46.8		.744+00	.696+00	.640+00	.578+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.421-01	.452-01	.587-01	.723-01	.858-01	.994-01	.113+00	.126+00	.140+00	.154+00	.167+00	.181+00	
-48.3		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.351-01	.541-01	.704-01	.866-01	.103+00	.119+00	.135+00	.152+00	.168+00	.184+00	.200+00	.216+00	
-49.7		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.292-01	.650-01	.845-01	.104+00	.124+00	.143+00	.163+00	.182+00	.202+00	.221+00	.241+00	.260+00	
-51.2		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.243-01	.783-01	.102+00	.125+00	.149+00	.172+00	.196+00	.219+00	.243+00	.266+00	.290+00	.313+00	
-52.7		.508+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.201-01	.945-01	.123+00	.151+00	.180+00	.208+00	.236+00	.265+00	.293+00	.321+00	.350+00	.378+00	
-54.2		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.688-01	.500
	.166-01	.114+00	.149+00	.183+00	.217+00	.252+00	.286+00	.320+00	.355+00	.389+00	.423+00	.458+00	
-55.7		.354+00	.331+00	.305+00	.275+00	.242+00	.206+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.137-01	.139+00	.181+00	.222+00	.264+00	.306+00	.347+00	.389+00	.431+00	.472+00	.514+00	.556+00	
-57.2		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.112-01	.169+00	.220+00	.271+00	.321+00	.372+00	.423+00	.473+00	.524+00	.575+00	.626+00	.676+00	
-58.7		.222+00	.208+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.921-02	.206+00	.268+00	.330+00	.392+00	.454+00	.516+00	.578+00	.640+00	.702+00	.764+00	.826+00	
-60.2		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.752-02	.253+00	.328+00	.404+00	.480+00	.556+00	.632+00	.707+00	.783+00	.859+00	.935+00	.101+01	
-61.7		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.613-02	.310+00	.403+00	.496+00	.589+00	.682+00	.776+00	.869+00	.962+00	.105+01	.115+01	.124+01	
		.862	.807	.742	.670	.589	.500	.411	.330	.258	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

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TABLE 8. Climate for 40°N Latitude
14.0 km Altitude 141.0 MB Pressure
(Joint Probability/Relative Humidity).

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EV, MM HG

TC DEG C	PSAT MM HG	.471-03	.612-03	.753-03	.894-03	.104-02	.118-02	.132-02	.146-02	.160-02	.174-02	.188-02	PROB TEMP IS LT TC
-51.6		.744+00	.696+00	.640+00	.578+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.225-01	.209-01	.272-01	.334-01	.397-01	.460-01	.522-01	.585-01	.648-01	.710-01	.773-01	.836-01	
-53.3		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.188-01	.250-01	.326-01	.401-01	.476-01	.551-01	.626-01	.701-01	.776-01	.851-01	.926-01	.100+00	
-54.7		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.156-01	.301-01	.391-01	.481-01	.572-01	.662-01	.752-01	.842-01	.933-01	.102+00	.111+00	.120+00	
-56.1		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.130-01	.362-01	.471-01	.580-01	.689-01	.797-01	.906-01	.101+00	.112+00	.123+00	.134+00	.145+00	
-57.6		.506+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.108-01	.438-01	.569-01	.700-01	.832-01	.963-01	.109+00	.123+00	.136+00	.149+00	.162+00	.175+00	
-59.0		.431+00	.403+00	.371+00	.335+00	.295+00	.253+00	.206+00	.165+00	.129+00	.968-01	.688-01	.500
	.888-02	.530-01	.689-01	.848-01	.101+00	.117+00	.132+00	.148+00	.164+00	.180+00	.196+00	.212+00	
-60.4		.354+00	.331+00	.305+00	.275+00	.242+00	.205+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.731-02	.643-01	.836-01	.103+00	.122+00	.142+00	.161+00	.180+00	.199+00	.219+00	.238+00	.257+00	
-61.9		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.601-02	.783-01	.102+00	.125+00	.149+00	.172+00	.196+00	.219+00	.243+00	.266+00	.290+00	.313+00	
-63.3		.222+00	.208+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.492-02	.956-01	.124+00	.153+00	.182+00	.210+00	.239+00	.268+00	.296+00	.325+00	.354+00	.382+00	
-64.7		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.402-02	.117+00	.152+00	.187+00	.222+00	.257+00	.293+00	.328+00	.363+00	.398+00	.433+00	.468+00	
-66.2		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.328-02	.144+00	.167+00	.230+00	.273+00	.316+00	.359+00	.402+00	.445+00	.488+00	.532+00	.575+00	
		.862	.807	.742	.670	.589	.530	.411	.330	.259	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

**TABLE 9. Climate for 50°N Latitude
2.0 km Altitude 795.0 MB Pressure
(Joint Probability/Relative Humidity).**

EV, MM HG

TC DEG C	PSAT MM HG	.794+00	.103+01	.127+01	.151+01	.175+01	.198+01	.222+01	.246+01	.270+01	.294+01	.318+01	PROB TEMP IS LT TC
9.5		.744+00	.696+00	.640+00	.576+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.881+01	.901-01	.117+00	.144+00	.171+00	.198+00	.225+00	.252+00	.279+00	.306+00	.333+00	.360+00	
6.7		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.728+01	.109+00	.142+00	.174+00	.207+00	.240+00	.273+00	.305+00	.338+00	.371+00	.404+00	.436+00	
3.9		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.599+01	.133+00	.172+00	.212+00	.252+00	.292+00	.331+00	.371+00	.411+00	.451+00	.491+00	.530+00	
1.1		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.490+01	.162+00	.211+00	.259+00	.308+00	.356+00	.405+00	.453+00	.502+00	.551+00	.599+00	.648+00	
-1.7		.508+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.400+01	.199+00	.258+00	.318+00	.377+00	.437+00	.497+00	.556+00	.616+00	.675+00	.735+00	.795+00	
-4.5		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.688-01	.500
	.324+01	.245+00	.318+00	.392+00	.465+00	.539+00	.612+00	.686+00	.759+00	.832+00	.906+00	.979+00	
-7.3		.354+00	.331+00	.305+00	.275+00	.242+00	.206+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.262+01	.303+00	.394+00	.485+00	.576+00	.667+00	.757+00	.848+00	.939+00	.103+01	.112+01	.121+01	
-10.1		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.211+01	.376+00	.489+00	.602+00	.715+00	.828+00	.941+00	.105+01	.117+01	.128+01	.139+01	.151+01	
-12.9		.222+00	.208+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.169+01	.470+00	.611+00	.751+00	.892+00	.103+01	.117+01	.132+01	.146+01	.160+01	.174+01	.188+01	
-15.7		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.111+01	.715+00	.929+00	.114+01	.136+01	.157+01	.179+01	.200+01	.222+01	.243+01	.265+01	.286+01	
-18.5		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.655+00	.928+00	.121+01	.149+01	.176+01	.204+01	.232+01	.260+01	.288+01	.316+01	.343+01	.371+01	
PROBABILITY THAT HUMIDITY .GT. EV		.862	.807	.742	.670	.589	.500	.411	.330	.258	.194	.138	

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TABLE 10. Climate for 50°N Latitude 4.0 km Altitude 616.0 MB Pressure (Joint Probability/Relative Humidity).

EV, MM HG

TC DEG C	P SAT MM HG	.254+00	.330+00	.407+00	.483+00	.559+00	.635+00	.712+00	.788+00	.864+00	.940+00	.102+01	PROB TEMP IS LT TC
-6.0		.744+00	.696+00	.640+00	.578+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.289+01	.878-01	.114+00	.140+00	.167+00	.193+00	.219+00	.246+00	.272+00	.298+00	.325+00	.351+00	
-8.6		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.238+01	.107+00	.139+00	.171+00	.203+00	.235+00	.267+00	.299+00	.331+00	.363+00	.395+00	.427+00	
-11.1		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.195+01	.131+00	.170+00	.209+00	.248+00	.287+00	.326+00	.365+00	.405+00	.444+00	.483+00	.522+00	
-13.7		.576+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.159+01	.160+00	.208+00	.256+00	.304+00	.352+00	.400+00	.448+00	.496+00	.544+00	.592+00	.640+00	
-16.2		.508+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.106+01	.240+00	.313+00	.385+00	.457+00	.529+00	.601+00	.673+00	.745+00	.818+00	.890+00	.962+00	
-18.6		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.688-01	.500
	.832+00	.305+00	.397+00	.489+00	.580+00	.672+00	.764+00	.855+00	.947+00	.104+01	.113+01	.122+01	
-21.3		.354+00	.331+00	.305+00	.275+00	.242+00	.206+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.652+00	.390+00	.507+00	.624+00	.741+00	.858+00	.975+00	.109+01	.121+01	.133+01	.144+01	.156+01	
-23.9		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.508+00	.500+00	.651+00	.801+00	.951+00	.110+01	.125+01	.140+01	.155+01	.170+01	.185+01	.200+01	
-26.4		.222+00	.208+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.394+00	.646+00	.839+00	.103+01	.123+01	.142+01	.161+01	.181+01	.200+01	.219+01	.239+01	.258+01	
-29.0		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.304+00	.837+00	.109+01	.134+01	.159+01	.184+01	.209+01	.234+01	.260+01	.285+01	.310+01	.335+01	
-31.5		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.233+00	.109+01	.142+01	.175+01	.207+01	.240+01	.273+01	.306+01	.339+01	.371+01	.404+01	.437+01	
		.862	.807	.742	.670	.589	.500	.411	.330	.258	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

TABLE 11. Climate for 50°N Latitude 6.0 km Altitude 472.0 MB Pressure (Joint Probability/Relative Humidity).

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EV, MM HG

TC DEG C	PSAT MM HG	.804-01	.105+00	.129+00	.153+00	.177+00	.201+00	.225+00	.249+00	.273+00	.298+00	.322+00	PROB TEMP IS LT TC
-19.1		.744+00	.696+00	.640+00	.578+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.803+00	.100+00	.130+00	.160+00	.190+00	.220+00	.250+00	.280+00	.310+00	.340+00	.371+00	.401+00	
-21.5		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.642+00	.125+00	.163+00	.201+00	.238+00	.276+00	.313+00	.351+00	.388+00	.426+00	.464+00	.501+00	
-23.8		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.511+00	.156+00	.205+00	.252+00	.299+00	.347+00	.394+00	.441+00	.488+00	.536+00	.583+00	.630+00	
-26.2		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.404+00	.199+00	.259+00	.318+00	.378+00	.437+00	.497+00	.557+00	.616+00	.676+00	.736+00	.795+00	
-28.5		.506+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.319+00	.252+00	.328+00	.403+00	.479+00	.555+00	.630+00	.706+00	.782+00	.857+00	.933+00	.101+01	
-30.8		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.688-01	.500
	.250+00	.321+00	.418+00	.514+00	.611+00	.707+00	.803+00	.900+00	.996+00	.109+01	.119+01	.129+01	
-33.2		.354+00	.331+00	.305+00	.275+00	.242+00	.206+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.196+00	.411+00	.535+00	.658+00	.782+00	.905+00	.103+01	.115+01	.128+01	.140+01	.152+01	.165+01	
-35.5		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.152+00	.529+00	.688+00	.847+00	.101+01	.116+01	.132+01	.148+01	.164+01	.180+01	.196+01	.212+01	
-37.9		.222+00	.206+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.116+00	.684+00	.890+00	.110+01	.130+01	.151+01	.171+01	.192+01	.212+01	.233+01	.253+01	.274+01	
-40.2		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.904-01	.890+00	.116+01	.142+01	.169+01	.196+01	.222+01	.249+01	.276+01	.303+01	.329+01	.356+01	
-42.5		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.692-01	.116+01	.151+01	.186+01	.221+01	.256+01	.291+01	.326+01	.361+01	.395+01	.430+01	.465+01	
		.862	.807	.742	.670	.589	.500	.411	.330	.258	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

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TABLE 12. Climate for 50°N Latitude
8.0 km Altitude 356.0 MB Pressure
(Joint Probability/Relative Humidity).

EV, MM HG

TC DEG C	PSAT MM HG	.251-01	.326-01	.401-01	.476-01	.551-01	.626-01	.702-01	.777-01	.852-01	.927-01	.100+00	PROB TEMP IS LT TC
-30.0		.744+00	.696+00	.640+00	.576+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.275+00	.913-01	.119+00	.146+00	.173+00	.201+00	.228+00	.256+00	.283+00	.310+00	.338+00	.365+00	
-32.1		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.219+00	.114+00	.149+00	.183+00	.217+00	.252+00	.286+00	.320+00	.354+00	.389+00	.423+00	.457+00	
-34.3		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.174+00	.144+00	.187+00	.230+00	.273+00	.317+00	.360+00	.403+00	.446+00	.489+00	.532+00	.575+00	
-36.4		.576+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.138+00	.182+00	.236+00	.291+00	.345+00	.400+00	.454+00	.509+00	.564+00	.618+00	.673+00	.727+00	
-38.6		.508+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.109+00	.231+00	.300+00	.369+00	.438+00	.508+00	.577+00	.646+00	.715+00	.784+00	.854+00	.923+00	
-40.7		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.688-01	.500
	.852-01	.294+00	.362+00	.470+00	.559+00	.647+00	.735+00	.823+00	.912+00	.100+01	.109+01	.118+01	
-42.9		.354+00	.331+00	.305+00	.275+00	.242+00	.205+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.665-01	.377+00	.490+00	.603+00	.716+00	.828+00	.941+00	.105+01	.117+01	.128+01	.139+01	.151+01	
-45.0		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.517-01	.485+00	.630+00	.775+00	.921+00	.107+01	.121+01	.136+01	.150+01	.165+01	.179+01	.194+01	
-47.2		.222+00	.208+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.400-01	.627+00	.815+00	.100+01	.119+01	.138+01	.157+01	.175+01	.194+01	.213+01	.232+01	.251+01	
-49.3		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.308-01	.814+00	.106+01	.130+01	.155+01	.179+01	.204+01	.228+01	.252+01	.277+01	.301+01	.326+01	
-51.5		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.236-01	.106+01	.138+01	.170+01	.202+01	.234+01	.265+01	.298+01	.330+01	.362+01	.394+01	.426+01	
		.862	.607	.742	.670	.589	.500	.411	.330	.258	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

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TABLE 13. Climate for 50°N Latitude 10.0 km Altitude 264.0 MB Pressure (Joint Probability/Relative Humidity).

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EV, MM HG

TC DEG C	P SAT MM HG	.767-02	.996-02	.123-01	.146-01	.169-01	.192-01	.215-01	.236-01	.261-01	.284-01	.307-01	PROB TEMP IS LT TC
-38.4		.744+00	.696+00	.640+00	.578+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.110+00	.697-01	.906-01	.111+00	.132+00	.153+00	.174+00	.195+00	.216+00	.237+00	.258+00	.279+00	
-40.4		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.680-01	.872-01	.113+00	.140+00	.166+00	.192+00	.218+00	.244+00	.270+00	.296+00	.323+00	.349+00	
-42.4		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.700-01	.110+00	.142+00	.175+00	.208+00	.241+00	.274+00	.307+00	.340+00	.373+00	.405+00	.438+00	
-44.4		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.555-01	.138+00	.180+00	.221+00	.263+00	.304+00	.345+00	.387+00	.428+00	.470+00	.511+00	.553+00	
-46.4		.506+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.610-01	.589
	.438-01	.175+00	.228+00	.280+00	.333+00	.385+00	.438+00	.490+00	.543+00	.595+00	.648+00	.700+00	
-48.4		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.686-01	.500
	.344-01	.223+00	.290+00	.356+00	.423+00	.490+00	.557+00	.624+00	.691+00	.757+00	.824+00	.891+00	
-50.4		.354+00	.331+00	.305+00	.275+00	.242+00	.206+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.270-01	.285+00	.370+00	.455+00	.541+00	.626+00	.712+00	.797+00	.883+00	.968+00	.105+01	.114+01	
-52.4		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.210-01	.365+00	.475+00	.585+00	.694+00	.804+00	.914+00	.102+01	.113+01	.124+01	.135+01	.146+01	
-54.4		.222+00	.208+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.163-01	.471+00	.613+00	.754+00	.895+00	.104+01	.118+01	.132+01	.146+01	.160+01	.174+01	.189+01	
-56.4		.167+00	.156+00	.144+00	.130+00	.114+00	.963-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.126-01	.611+00	.794+00	.977+00	.116+01	.134+01	.153+01	.171+01	.189+01	.208+01	.226+01	.244+01	
-53.4		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.965-02	.795+00	.103+01	.127+01	.151+01	.175+01	.199+01	.223+01	.247+01	.270+01	.294+01	.318+01	
		.862	.807	.742	.670	.589	.500	.411	.330	.258	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

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TABLE 14. Climate for 50°N Latitude 12.0 km Altitude 193.0 MB Pressure (Joint Probability/Relative Humidity).

****

EV, MM HG

TC DEG C	P SAT MM HG	.190-02	.247-02	.304-02	.361-02	.418-02	.475-02	.532-02	.589-02	.646-02	.703-02	.760-02	PROB TEMP IS LT TC
-44.6		.744+00	.696+00	.640+00	.578+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.543-01	.350-01	.455-01	.560-01	.665-01	.770-01	.875-01	.980-01	.108+00	.119+00	.129+00	.140+00	
-46.5		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.436-01	.436-01	.567-01	.698-01	.829-01	.960-01	.109+00	.122+00	.135+00	.148+00	.161+00	.175+00	
-48.3		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.346-01	.546-01	.710-01	.874-01	.104+00	.120+00	.137+00	.153+00	.169+00	.186+00	.202+00	.219+00	
-50.2		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.277-01	.687-01	.893-01	.110+00	.130+00	.151+00	.172+00	.192+00	.213+00	.233+00	.254+00	.275+00	
-52.0		.508+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.219-01	.866-01	.113+00	.139+00	.165+00	.191+00	.217+00	.243+00	.269+00	.295+00	.321+00	.347+00	
-53.9		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.968-01	.686-01	.500
	.173-01	.110+00	.143+00	.176+00	.209+00	.241+00	.274+00	.307+00	.340+00	.373+00	.406+00	.439+00	
-55.8		.354+00	.331+00	.305+00	.275+00	.242+00	.206+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.136-01	.140+00	.181+00	.223+00	.265+00	.307+00	.349+00	.391+00	.433+00	.475+00	.517+00	.558+00	
-57.6		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.107-01	.178+00	.232+00	.285+00	.339+00	.392+00	.446+00	.499+00	.553+00	.606+00	.660+00	.713+00	
-59.5		.222+00	.206+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.831-02	.229+00	.298+00	.366+00	.435+00	.503+00	.572+00	.641+00	.709+00	.778+00	.847+00	.915+00	
-61.4		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.644-02	.295+00	.383+00	.472+00	.560+00	.649+00	.737+00	.826+00	.914+00	.100+01	.109+01	.118+01	
-63.2		.119+00	.111+00	.102+00	.921-01	.810-01	.686-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.498-02	.382+00	.497+00	.611+00	.726+00	.840+00	.955+00	.107+01	.118+01	.130+01	.141+01	.153+01	
		.862	.807	.742	.670	.589	.500	.411	.330	.258	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

TABLE 15. Climate for 50°N Latitude 14.0 km Altitude 141.0 MB Pressure (Joint Probability/Relative Humidity).

EV, MM HG

TC DEG C	PSAT MM HG	.471-03	.612-03	.753-03	.894-03	.104-02	.118-02	.132-02	.146-02	.160-02	.174-02	.188-02	PROB TEMP IS LT TC
-48.4		.744+00	.696+00	.640+00	.578+00	.508+00	.431+00	.354+00	.285+00	.222+00	.167+00	.119+00	.862
	.343-01	.137-01	.178-01	.220-01	.261-01	.302-01	.343-01	.384-01	.425-01	.467-01	.508-01	.549-01	
-50.2		.696+00	.650+00	.599+00	.540+00	.475+00	.403+00	.331+00	.266+00	.208+00	.156+00	.111+00	.807
	.276-01	.170-01	.221-01	.272-01	.324-01	.375-01	.426-01	.477-01	.528-01	.579-01	.630-01	.681-01	
-52.0		.640+00	.599+00	.551+00	.497+00	.437+00	.371+00	.305+00	.245+00	.191+00	.144+00	.102+00	.742
	.222-01	.212-01	.276-01	.339-01	.403-01	.466-01	.530-01	.594-01	.657-01	.721-01	.784-01	.848-01	
-53.7		.578+00	.540+00	.497+00	.449+00	.394+00	.335+00	.275+00	.221+00	.173+00	.130+00	.921-01	.670
	.178-01	.265-01	.344-01	.424-01	.503-01	.583-01	.662-01	.742-01	.821-01	.901-01	.980-01	.106+00	
-55.5		.506+00	.475+00	.437+00	.394+00	.347+00	.295+00	.242+00	.195+00	.152+00	.114+00	.810-01	.589
	.142-01	.332-01	.432-01	.531-01	.631-01	.731-01	.830-01	.930-01	.103+00	.113+00	.123+00	.133+00	
-57.2		.431+00	.403+00	.371+00	.335+00	.295+00	.250+00	.206+00	.165+00	.129+00	.966-01	.688-01	.500
	.113-01	.416-01	.544-01	.669-01	.794-01	.920-01	.105+00	.117+00	.130+00	.142+00	.155+00	.167+00	
-59.0		.354+00	.331+00	.305+00	.275+00	.242+00	.206+00	.169+00	.136+00	.106+00	.795-01	.565-01	.411
	.891-02	.528-01	.687-01	.845-01	.100+00	.116+00	.132+00	.148+00	.164+00	.180+00	.195+00	.211+00	
-60.7		.285+00	.266+00	.245+00	.221+00	.195+00	.165+00	.136+00	.109+00	.851-01	.639-01	.454-01	.330
	.702-02	.670-01	.871-01	.107+00	.127+00	.147+00	.168+00	.188+00	.208+00	.228+00	.248+00	.268+00	
-62.5		.222+00	.208+00	.191+00	.173+00	.152+00	.129+00	.106+00	.851-01	.664-01	.499-01	.354-01	.258
	.551-02	.854-01	.111+00	.137+00	.162+00	.188+00	.213+00	.239+00	.265+00	.290+00	.316+00	.342+00	
-64.2		.167+00	.156+00	.144+00	.130+00	.114+00	.968-01	.795-01	.639-01	.499-01	.374-01	.266-01	.194
	.431-02	.109+00	.142+00	.175+00	.208+00	.240+00	.273+00	.306+00	.339+00	.371+00	.404+00	.437+00	
-66.0		.119+00	.111+00	.102+00	.921-01	.810-01	.688-01	.565-01	.454-01	.354-01	.266-01	.189-01	.138
	.335-02	.140+00	.182+00	.224+00	.267+00	.309+00	.351+00	.393+00	.435+00	.477+00	.519+00	.561+00	
		.862	.807	.742	.670	.589	.500	.411	.330	.258	.194	.138	

PROBABILITY THAT HUMIDITY .GT. EV

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Appendix
COMPUTER PROGRAM FOR GENERATING PROBABILITY TABLES

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      C
      C*** PROGRAM TO CALCULATE CLIMATE AT 40 AND 50 DEG NORTH LATITUDE
      C****CORRECTED VERSION, 4 JAN 1979
      C
      C      Y  IS ALTITUDE, KM
      C      XLAT  IS LATITUDE, DEG N
      C      PATM  IS ATMOSPHERIC PRESSURE IN MB
      C
             DIMENSION H(11),PH(11),PT(11),PJ(11),RH(11),PHH(11),PTT(11)
           5 READ(5,100,END=75) Y,XLAT,PATM
             WRITE(6,200)XLAT,Y,PATM
             IF(XLAT.LT.50.) GO TO 10
      C
      C      FOR LAT = 50 DEG N
      C
             TEMP=12.95-8.774*Y+.2738*Y**2.
             TE = 10.3-0.7*Y+.0167*Y**2.
             SIGU = 6.
             SIGL = 4.
             TU= TEMP+TE+SIGL
             TL = TEMP-TE-SIGU
             GO TO 20
      C      FOR LATITUDE = 40 DEG N
          10 TEMP = 28.56-10.618*Y+.3168*Y**2.
             TE = 8. - .56*Y +.0153*Y**2.
             SIGU = 5.
             SIGL = 3.
             IF(Y.GT.14.) GO TO 15
             TU = TEMP + TE + SIGL
             TL = TEMP - TE - SIGU
             GO TO 20
          15 TU = TEMP + TE + SIGU
             TL = TEMP - TE - SIGL
      C      CALCULATE HUMIDITY
          20 IF(Y.GT.10.) GO TO 21
             W = 10.**(3.7 - .192*Y)
             GO TO 22
          21 W = 10.**(4.13 - .235*Y)
          22 EV = PATM * W/622000.
             EVHG = EV*.7502
             EVHGU = 1.6*EVHG
             EVHGL = .4*EVHG
      C      CALCULATE TEMPERATURE STATISTICS
             BT = (TU - TL)/.72
             AT = TL - .14*BT
      C      CALCULATE HUMIDITY STATISTICS
             BH = -(EVHGU - EVHGL)/.72
             AH = EVHGU - .14*BH
      C      CALCULATE JOINT PROBABILITIES AND RELATIVE HUMIDITIES
             PH(1) = .8625
             PHH(1) = .86
             DO 30 I = 1,11
             H(I) = AH + PHH(I)*BH
             IF(I.LE.5) DED =(0.825*(I-1) +5.6)*.01
             IF(I.GT.5) DED =(0.825*(10-I) + 5.6)*.01
             PH(I+1) = PH(I) - DED
             PHH(I+1) = PHH(I) - .072
          30 CONTINUE
             WRITE(6,210)
             WRITE(6,220) (H(I),I=1,11)
```

```
      PT(1) = .8625
      PTT(1) = .86
      DO 40 J=1,11
      TC = AT + PTT(J)*BT
      T = TC + 273.
      IF(T.LT.258.) GO TO 520
  510 VPS  =(((.135601E-7*T-.151036E-4)*T+.00618156)*T-1.07005)*T+64.058
      GO TO 530
  520 VPS=(((.538009E-05-.473762E -08*T)*T-.00243188)*T+.545827)*T-50.27
     1189
  530 VPS = 10.**VPS
      PH(1) = .8625
      DO 35 I =1,11
      PJ(I) = PH(I)*PT(J)
      RH(I) = H(I)/VPS
   35 CONTINUE
      WRITE(6,230)TC,(PJ(I),I=1,11),PT(J)
      WRITE(6,240)VPS,(RH(I),I=1,11)
      IF(J.LE.5) DED =(0.825*(J-1) +5.6)*.01
      IF(J.GT.5) DED =(0.825*(10-J) + 5.6)*.01
      PT(J+1) = PT(J) - DED
      PTT(J+1) = PTT(J) - .072
   40 CONTINUE
      WRITE(6,250) (PH(I),I=1,11)
      WRITE(6,260)
      GO TO 5
   75 CALL EXIT
  100 FORMAT()
  200 FORMAT(1H1T41,'CLIMATE FOR ',F4.1,'DEG. N LATITUDE' /T40,F4.1,'KM
     1ALTITUDE',F6.1,' MB PRESSURE', /T40,'(JOINT PROBABILITY / RELATIVE
     2 HUMIDITY )'/T45,'**********************'/T50,'EV, MM HG')
  210 FORMAT(1H0,'TC',T9,'PSAT',T109,'PROB TEMP IS')
  220 FORMAT(1H ,'DEG C',T9,'MM HG',T17,11E8.3,6X'LT TC')
  230 FORMAT ( /1H F6.1,T17,11E8.3,F8.3)
  240 FORMAT(1H T9,12E8.3)
  250 FORMAT(1H0T15,11F8.3)
  260 FORMAT(1H T40,'PROBABILITY THAT HUMIDITY .GT. EV')
      END
```


30

END

DATE
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